The spring forces will attract or repulse the bodies until the system reaches minimum energy. This is called the balanced state.

For flattening, first a rectangular mesh of nodal points connected by springs is generated from a subset of the point cloud or 3D coordinates of the smooth or average approximated surface, as shown in FIG. **14***a* step **806**. The virtual springs have a relaxation distance equal to the Euclidean distance between two points of the 3D space of the handprint images. In step **808**, these points are then projected onto a 2D surface in step **810**. In step **812**, the points are allowed to iteratively expand thereby reducing the total energy built into each string. The energy stored in the virtual springs connecting a point in the mesh to the 8-connected neighbors has to be minimized. To minimize this energy, only the point whose displacement is being calculated moves and the remaining points remain fixed. The displacement of the point is iterative and every iteration consists of one pass over all the points in the mesh. To evaluate the total energy e at a point, the energy stored in each spring connecting the point to its neighbors is added together,

$$e = \sum_{i=1}^{n} e_i$$

The individual energy e_i is computed by squaring the magnitude of the displacement between the current length of the spring and its relaxed length. The sign of the displacement vector determines the type of force, attractive or repulsive that has to be applied to the spring in order to achieve the balanced state. The energy stored in the ith spring is hence determined by,

$$e_i = \text{sign}(d_i - r_i) \cdot (d_i - r_i)^2$$

where, d_i is the current length which is taken to be the Euclidean distance between the points in the 2-D space and r_i is the relaxed length of the i^{th} spring determined by the Euclidean distance between the points in the 3-D space. The energy in each spring is then assigned the direction of the displacement vector and added to the total energy e at the point under consideration. To attain the equilibrium state, the point has to move depending on the energy stored at that point. A percentage amount, π, of the total energy is used to displace the mesh point in the 2-D space. The value of λ must be chosen to prevent making the system unstable, e.g. large values of λ can make the system unstable. FIG. **14***c* shows a simulation **830** of the algorithm in one-dimensional space in the X-Y plane. The points marked as stars (*) are the initial 2-D nodal mesh given as input to the springs algorithm. The points marked as blank circles (o), are positions of the same points after 1000 iterations of the Springs algorithm. As the number of iterations increase, the points move in the 2-D space to attain an equilibrium state. The balanced state is achieved when the distance between these points is equal to their Euclidean distance in the 3-D space.

FIG. **14***d* illustrates the 2D rolled equivalent fingerprint **840** generated from the unraveled fingerprint surface, obtained by applying the springs algorithm to the fingerprint scan shown in FIG. **14***b*. The 2-D unraveled nodal points in FIG. **14***d* were obtained after 5,000 iterations. Since only a subset of the 3D coordinates of the original handprint scan were assigned as nodal points in the mesh, any of the other unassigned 3D coordinates may be assigned within the 2D mesh of unraveled nodal points.

In step **814**, the extracted fingerprint surface, obtained from the extraction step **804**, is warped as a color component onto the 2-D nodal mesh to generate the 2D rolled equivalent fingerprint in FIG. **14***d*. Each of the points in the 2D mesh of unraveled nodal points are assigned a ridge height information from the fingerprint surface extracted in step **802**. Any other detailed fingerprint surface information extracted in step **802** can be warped around as the color component as well. To obtain points or pixels at regular intervals, the resulting 2D unraveled mesh of nodal points with detailed handprint surface information may be sampled along a grid lattice to create the 2-D rolled equivalent image.

Histogram manipulation may also be applied to match the fingerprint histograms of existing, high quality scans within a target database. This histogram manipulation may be done during the processing to aid in further processing or at the end of the processing to match the fingerprint with an identity.

The embodiments of the biometrics system **100** described herein have various advantages over the prior art. For example, speed of acquisition of the handprint images is greatly increased from the 5-10 minutes of rolled ink fingerprinting. Translucent sweat or oil will not corrupt the handprint images nor will common variations in skin color. The biometrics system **100** is robust to translucent materials and resistant to specularity of shiny surfaces. The biometrics system **100** is more robust to extremely worn ridges of the fingers and palm.

Though the present embodiment has been described for obtaining a hand print, a person of skill in the art would appreciate that the system may be modified for obtaining images for other biometrics, such as scars, tattoos, facial features, etc. The present system may also be used in other fields besides biometrics. For example, in medical fields, the present invention may be used for measuring moles on skin surfaces or other features that need to be recorded, measured or monitored. Other uses include Human Computer Interaction, prosthetic development, industrial inspection, special effects and others.

While certain representative embodiments have been described herein, a person of skill in the art would appreciate that various substitutions, modifications or configurations other than those described herein may be used and are within the scope of the claims of the present invention.

What is claimed is:

1. A three dimensional (3D) imaging system using a structured light illumination technique, comprising:
- at least one projection unit for projecting a series of structured light patterns onto a 3D object, wherein the series of structured light patterns includes:
  - a first series of triangle waveforms at a first frequency each in a first color, wherein each of the triangle waveforms in the first series has a different phase;
  - a second series of triangle waveforms at a second frequency each in a second color, wherein each of the triangle waveforms in the second series has a different phase;
- one or more cameras for capturing at least one image of the 3D object with each structured light pattern in the series of structured light patterns projected onto the 3D object; and
- a processing unit for calculating coordinates of the 3D object from the images based on a phase value determined from one or more of the series of triangle waveforms.

2. The biometrics system of claim **1**, wherein the first frequency is a base frequency and the second frequency is a high frequency.